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MECHANICAL PROPERTIES OF THE PULPOSE NUCLEUS LUMBAR INTERVERTEB--ETC(U)
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by

Ya. L. Tsiv'yan, V. Kh. Raykhinshteyn, et al.

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П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

MECHANICAL PROPERTIES OF THE PULPOSE NUCLEUS OF LUMBAR INTERVERTEBRAL DISCS ACCORDING TO THE DATA OF BARODICOMETRY IN EXPERIMENT.

Prof. Ya. L. Tsiv'yan, senior scientific worker V. Kh. Raykhinshteyn, M. D. Mosolova and Ya. G. Ovseychik.

From clinical aspects of traumatology and orthopedy and division of the physiology of the Novosibirsk institute of traumatology and orthopedy (Dir., Docent D. P. Metelkin).

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In the beginning 1967 in clinical aspects cf traumatology and orthopedy of the Novosibirsk institute cf traumatology and orthopedy together with the division of physiology, is initiated extensive composite work on research on physiology and the mechanics of intervertebral disks.

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This work is dedicated to research on intra-disk pressure in pulpose nucleus of intervertebral lumbar disks of man during vertical compression in experiment on putrid material. Investigation is based on the use of the specially designed instrument, which allows to obtain precise quantitative pressure characteristic within disk.

Equipment/device needle-probe for recording of pressure. Sensor for pressure measurement in pulpose nucleus of disk is the injection needle with a diameter of 1.9 mm and length of 180 mm soldered on the end. A miniature tensometric device based on semiconductor where are cut two oval windows 4 x 1.3 mm in size/dimension of, displaced along the axis of relatively each other. The overall size of the sensitive part of the needle it does not exceed, thus, 1.5 x 10.0 mm. In elongated holes are fastened sensitive to pressure flexible metallic diaphragm/membranes. The connected with diaphragm/membranes strain gauges are switched on in the circuit of weak direct current on bridge system. Entire mechanism of instrument is placed in the lumen of needle. For convenience in the inversion, the needle is fastened to hollow crank.

During the introduction of needle into the nucleus of intervertabral disk, the pressure of pulpiform mass affects directly

the extrinsic surface of barosensitive diaphragm/membranes. Submembrane cavity, i.e., the canal of needle, is communicated with atmospheric pressure; under the action of pressure difference of diaphragm/membrane, they transform, which is led to a change in the electrical properties of the connected with them semiconductor sensors. The output signal of strain gage can be recorded by the appropriate electrical indicator instrument without any intermediate component/links and amplifiers. In our experiments as recorder, most frequently were utilized the laboratory instrument of magnitoelectric system with a shadow arrow/pointer of the type M-193 or leveler radial oscillograph N-700.

Readings of recorder preliminarily were calibrated in special calibrator in the range from 0 to 20 kg/cm^2. Numerous calibrations to, during experiment and afterward showed that the properties and the sensitivity of needle probe do not change.

The subject of investigations was putrid material. In order to eliminate the effect on the studied indicators of prolonged diseases and intoxications, were investigated only the preparations of the subjects, killed as a result of accidents (without the damages of spine).

Experiments were carried out on: a) whole preparation of the

lumbar division of the spine from which preliminarily were intercept/detached the thoroughly prepared muscles: b) the disks, included between the half-bodies of two adjacent vertebrae with the preserved extensions and bundle apparatus; c) the disks, included between the half-bodies of two adjacent vertebrae with the cut off rear side cell/elements.

Procedure of experiment. Preparations underwent vertical compression in circular the jaws of the specially designed compression apparatus, working compressed gas. The gas pressure was measured at the entrance into apparatus by manometer with scale value 0.125 kg/cm^2. The carried out preliminarily calculations (taking into account the pressure of gas and piston clearance of working cylinder) made it possible to have a representation of total load on the investigated disk in kilograms with an accuracy to 0.5 kg. Recording intra-disk pressure was carried out with the increasing loads from 0 to 200 kg: 0, 25, 50, 75, 100, 150 and 200 kg - precisely these loads lie/rest within the limits of the physiological possibilities of the man of average physical development.

By the subject of investigation was prepared in a described manner the undifferentiated preparation of the lumbar division of spine. The sensitive part of discometric needle was introduced into studied disk, after which was measured its own pressure within disk

in the unloaded preparation. Then the block/module/unit of the lumbar division of spine was placed into the jaws of compression apparatus and began recording pressure during compression with an increase in the loads. This procedure to a strict observance of identical conditions was repeated for all four intervertebral disks. After this the preparation was dismembered (line of sawing was passed through the middle of the body of vertebra in horizontal plane) and analogously was carried out recording barodiscometric indicators in the disk, included between the half-bodies of two adjacent vertebrae with the preserved rear side cell/elements and without them.

At the end of the experiment, was conducted the transverse dissection of disks in parallel to the joint body surfaces of vertebrae, also, as far as possible in the plane of the puncture of discometric needle. This dissection necessary was for the calculation of the cross-sectional flow of disk and macroscopic estimation of the degree of degenerate changes.

The calculation of cross-sectional flow was realized in order to have the capability to compare these, obtained in disks of various forms and values.

For this purpose, the disk being investigated was establish/installed by the surface of section/shear to the millimeter graph paper and was encircled on outline by fine/thin slate pencil. The area of the encircled surface was measured with an accuracy to 1 mm².

The analysis of degenerate changes in the investigated disks was carried out macroscopically according to the most commonly used in the literature sign/criteria (Friberg a. Hirsch, 1949; Lindblom, 1944, 1951; Virgin, 1951, 1958; Naylor a. Smare, 1951; Hendry, 1958, Nachemson, 1960).

As a result of macroscopic analysis, the disks according to the degree of degeneration are divided for four groups.

I group - disks without any changes, noticeable for the naked eye. Is well visible the gelatinous substance of nucleus; nucleus was easyto separate from the annulus on which not could be seen breaks (see Fig., a).

II Group - disks with some macroscopic changes in the pulpose nucleus. Nucleus is more fibrous, but still differed well from invariable/unchanged annulus (see Fig., b).

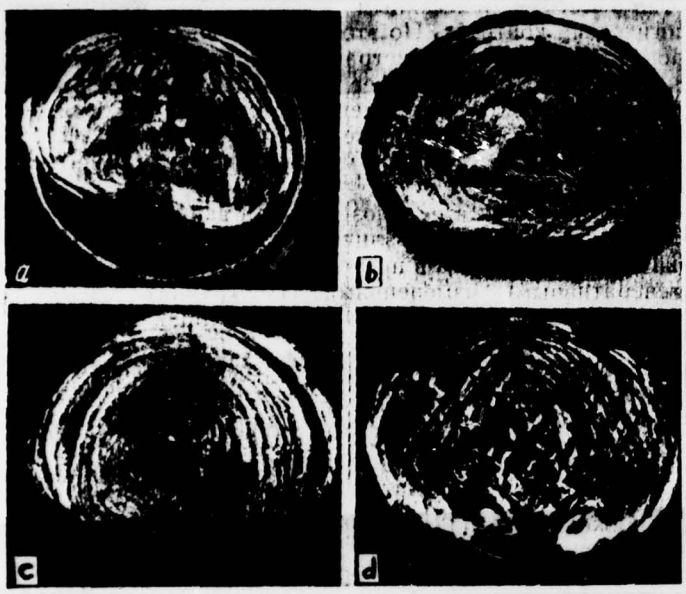
III Group - preparations had macroscopic changes in annulus and

nucleus. The nucleus of disk was even more fibrous, but softer. The boundary between the annulus and the nucleus was not so was distinct, but is still distinguished. Changes in fibrous annulus consisted in the presence of the separate slots (see Fig., c).

IV group - the disks of this group had heavy macroscopic changes. In annulus and nucleus, between which was not distinct boundary, were noted wide slots, cavities and packing/seals. Frequently in the adjacent vertebrae found boundary/edge osteophytes (see Fig., d).

In all during 30 preparations of the lumbar division of the spine it is investigated of 120 disks. Five Preparations were undertaken from subjects at the age of 18-28 years, 12 - from 30 of up to 38 years, 10 - from 40 of up to 46 years even 3 - from 51 of up to 64 years. In 23 cases were investigated men's preparations, in the others 7 - women's preparations. To preparations I of group it is referred of 46 disks, to II to group - 47, to III - 19 and to IV - 8 disks.

After experiment the transverse section/shear of disks were photographed. Obtained assay underwent statistical processing.



Transverse section/shear of the disks of the different degree of degeneration. a)disk I of group; b) the disk of II group; c) the disk of III group; d) disk IV of group.

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During the first stage of investigations (in 10 experiments on 40 disks) it was establish/installed that the created by us instrument very accurately records pressure in the invariable/unchanged and slightly-changed disks whose nuclei had homogenous structure. So, with the same amount cf compression forces

it was recorded identical pressure (deviations did not exceed 1-15o/o of absolute value) with the different points of the introduction of needle into disk, during the different orientations of sensitive to pressure diaphragm/membranes and on the different levels of the introduction (in horizontal plane) of needle into the thickness of disk. The determined value had the depth of the introduction of needle into disk, since incidence/impingement of one of the sensitive diaphragm/membranes beyond the limits of nucleus can distort the value of output signal. Therefore in a number of cases, besides the characteristic tactile perception of the determination of the sensitive part of the needle in pulpose nucleus and metric check (in terms of the marks, plotted/applied to log of needle), necessary was roentgenological check. For this same the reason is impossible for somewhat satisfactory recording of pressure in the strongly degenerated disks (IV and in a number of cases III group), since being in the nuclei of these disks of cavity and packing/seal they deprive of pulpose gel hydrcstatic properties, but the contact of sensitive diaphragm/membranes with heterogeneous in density sections disorganizes the normal operation of instrument.

The indicators of pressure in pulpose nucleus of the disks, in reference to I, II and III groups, outside load in different preparations were relatively variable and they cscillated within limits 0.5-2.0 kg/cm^2. In disks to gross degenerate changes (IV

group) to record any identical (under the varied conditions of the introduction of needle) its own pressure did not manage.

It is characteristic that after the cut-off of posterior semiring and transverse extensions together with bundle apparatus its own pressure in nucleus, as a rule, descended to 30-40o/o. In our view this fact attests to the fact that the bundle apparatus of the spine through rear side cell/elements of spinal column holds the bodies of vertebrae somewhat a reduced state, which, in turn, is led to certain increase in the voltage within the nucleus of disks.

The recorded by us in the majority of the invariable/unchanged and slightly-changed disks internal pressure of outside load, apparently, cannot be connected with supplementary volume that which was introduced into the substance of the nucleus of the sensitive part of the needle, since the calculations, which take into consideration the outside diameter of needle (1.9 mm) and the depth of its introduction into nucleus (it is not more than 20 mm) with the deduction of the volume of elongated holes, they show that this supplementary volume does not exceed 50 mm^3. On these Clowar a Buzaid (1952), Nachemson (1959, 1960), the total volume of gelatinous nuclear mass varies from 1000 to 6000 mm^3; thus, the volume of the sensitive part of the needle, introduced into nucleus, composes 1-3o/o of volume of nucleus.

In the second stage of investigation, we studied the reaction of intra-disk pressure on the dosed increasing vertical compression. It is establish/installed that with an increase in the forces of compression the recorded intra-disk pressure continuously grow/rises. However, by itself the fact of an increase in the pressure within disk during the intensification of compression still not about which says. For explaining the laws governing the reaction of intra-disk pressure on compression in different preparations, is necessary some common/general/total, relative indicator. This indicator is the relationship/ratio of external pressure on the unit of area of disk (this value is accepted as unit, or as 100o/o) with the intra-disk recorded pressure. External pressure on the unit of area of disk (designated as p) is easy to establish/install from the following formula:

$$p=\frac{w}{s},$$

where w is a value of the affecting disk load in kilograms, and s - the cross-sectional area of disk.

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In that case the mentioned relationship/ratio (designated as C) can

be expressed by the following equation:

$$C=\frac{P_1}{\frac{W}{s}}\cdot 100,$$

where P_1 - the recorded intra-disk pressure. The general law governing changes in this relationship/ratic with an increase in the forces of compression for disks of the I-III groups is reflected in table.

Analogous tables were comprised for each of the first three groups of preparations and for the disks, with identical level of the location in the lumbar division of spine. However, the carried out calculations showed the absence of the statistically reliable differences in the character/nature of the reactions of intra-disk pressure between the first three groups, on one hand, and the given above (see Table) law, on the other hand. Statistical processing also showed that the level of disk in lumbar division is not exerted a substantial influence on the indicators of intra-disk pressure, but age special feature/peculiarities were mainly connected with the degree of the degeneration of disk. In disks with gross degenerate changes, the development/detection of any laws was not presented possible.

As can be seen from table, the relationship/ratio of external pressure on the unit of area of disk with the recorded intra-disk

pressure is regularly connected with the value cf external load on disk. With light loads (25-50 kg) the pressure in pulpose nucleus of disk almost two times exceeds external pressure. With an increase in the forces of compression, this indicator descends, approaching a value of external pressure.

The obtained result cannot be, apparently, connected with an increase in the area of disk with the intensification of compression. On by Hirsch's datum, Nachemson, the increase of the area of disk during very sharp compression does not exceed 5-8o/o. Pulpose nucleus has the intercellular lymph, included between the grid/network of fibrils (Smorl, 1927; Calve a.Golland, 1930). Clowar a Buzaid they found that the gelatinous nuclear mass has incorrect ovoid form with the diameter of 1-2.5 cm. These data make it possible for us to consider nucleus as liquid medium, included into the elastic shell of annulus, which approaches a form of sphere. In this medium the pressure evenly is distributed in different directions. Under small forces of compression, the contact area of "sphere" with the jcint body surfaces of vertebrae is relatively small, which is led to a considerable increase in the relationship/ratio of pressure within disk with respect to pressure on the unit of area of disk as a whole. With an increase in the compression, elastic shell transformed, nucleus seemingly is flattened, which is led to an increase in its "bearing" surface with the bodies of vertebrae. Obviously, precisely,

this fact is led to a gradual decrease in ccefficient of C.

Findings can be interpreted as follows. With light vertical loads the dominant role of shock absorber taken on itself pulpose nucleus of disk, as if protecting fibrous annulus from the uncharacteristic to its nature forces of compression, in this case sharply grow/rise tensile strengths, which act on fibrous annulus. The structure of annulus is intended for the perception of tensile strengths.

Relationship/ratio of intra-disk pressure with external pressure on the unit of area of disk depending on the forces of compression for **I-III groups.**

(1) Компрессионная нагрузка в килограммах	25	50	75	100	150	200
(2) Соотношение внешнего давления на единицу площади диска с зарегистрированным внутридисковым давлением (С) в %.	200	180	165	150	140	130

Key: (1). Compression load in kilograms. (2). Relationship/ratio of external pressure on the unit of area of disk with the recorded intra-disk pressure (C) in o/o.

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With an increase in the load, the nucleus somewhat packed down, to fibrous annulus begin to affect additionally and the forces of compression.

Conclusions.

1. Pulpose nucleus of invariable/unchanged intervertebral lumbar disks during vertical compression under conditions of experiment detects hydrostatic properties. Vertical pressure evenly is distributed by entire volume of nucleus.

2. Reactions of nucleus as hydrostatic substance for compression are regular with different loads within limits of physiological boundaries.

3. Light loads during vertical compression are predominantly received by internal cell/elements of disk - pulpose nucleus; increasing forces of compression begin evenly to be distributed on all cell/elements of disk.

4. Roughly degenerated disks lose their properties of complex shock absorbers, being converted into semielastic packing between bodies of vertebrae.

MECHANICAL PROPERTIES OF NUCLEUS PULPOSUS OF THE LUMBAR INTERVERTEBRAL DISCS BASED ON DATA OF BARODISCOMETRY IN EXPERIMENT

J. L. Tzivyan, V. H. Raykhinstein, M. D. Mosolova and *J. G. Ovseytchik*

In this paper the response of the intervertebral lumbar discs to experimental vertical compression is elucidated. The object of study was cadaveric material. Variously treated preparations of the human lumbar spine were submitted to compressing load in a specially constructed apparatus. Barodiscometry — pressure in nucleus pulposus of the disc under static conditions was chosen as basic test. Information about the intradiscal pressure was obtained with aid of a special device — needle-probe of original construction. Discs of various degree of degeneration have been investigated. On basis of the experiments the authors propose a conception of the amortization functions of lumbar intervertebral discs.

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